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Lab. Project 5046-3, Part 49
Final Report
NS 081-001

AW-7

# MATERIAL LABORATORY

## NEW YORK NAVAL SHIPYARD
## BROOKLYN 1, N. Y.

# TECHNICAL REPORT



3ND-NYNS-900-P-1A

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Investigation of

# SPECTRAL REFLECTANCE AND TRANSMITTANCE of INTERIOR FUEL MATERIALS

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J.J. Schilling

Lab. Project 5046-3, Part 49
Final Report
NS 081-001
Technical Objective AW-7
AFSWP-394
2 November 1953

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## ABSTRACT

The spectral reflectance and transmittance of twenty-one materials employed within and around dwellings have been determined by the Material Laboratory. The total radiant absorptances computed from these data for 2000°K and 6000°K black-body radiation may be significantly different, even for black materials. In estimating the thermal energy from a given source required to damage a material on the basis of measurements utilizing a source of different spectral quality, suitable correction must be made for the absorptance of the material integrated over the spectrum of the source.

CONTENTS

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Ref: (a) FPL, USFS, ltr R-PL, Cooperation, AFSWP to NML of 31 Mar 1953
(b) COMNYKNAVSHIPYD conf ltr S99/L5, Ser 960-92, of 15 Mar 1950
(c) BUSHIPS rest. spdltr. C-S99(O)(346), Ser 348-75, of 6 Apr 1950

Encl: (1) Spectral Characteristics of Various Materials (21 Figures)
(2) Radiant Absorptances of Materials

## AUTHORITY

1. This investigation, which was requested by reference (a) and conducted by the Material Laboratory, is part of the program proposed by reference (b) and formally approved by reference (c). The general Thermal Radiation program is under the supervision of the Armed Forces Special Weapons Project.

## INTRODUCTION

2. The Forest Products Laboratory, U.S. Forest Service, Madison, Wis., under contract to the Armed Forces Special Weapons Project, is studying the behavior, under exposure to intense thermal radiation, of various materials which may serve as fuels in the event of an atomic explosion over an urban area. In studying the ignition characteristics of these materials and in attempting to correlate laboratory and field exposures, involving a source of radiation of relatively low temperature and one of relatively high temperature, the spectral reflectance, transmittance and absorptance of the materials are important factors in attempting to predict their behavior under exposure to a nuclear detonation.

3. The materials investigated included those which would be found in the interior of and about a typical dwelling . The materials were selected and submitted by the Forest Products Laboratory. The measurements included the spectral reflectance and spectral transmittance of the materials over the spectral region from 0.3 to 2.7 microns; the total absorptances of the materials for black-body radiation at 2000°K and 6000°K were computed from these data.

## METHODS OF MEASUREMENT

4. In general, the spectral transmittance and reflectance measurements were made over the spectral range from 0.32 to 2.7 microns. The Beckman Model DU Spectrophotometer[1] was employed for the measurements in the ultra-violet (0.32-0.4 microns). The General Electric Recording Spectrophotometer[2] was employed for the measurements in the visible and near-infrared regions (0.4-1.0 micron). For the transmittance measurements in the infrared region(1.0-2.7 microns), the Perkin-Elmer Infrared Spectrometer[3] was employed; for the reflectance measurements in the infrared region the spectrometer was used in conjunction with the NML-designed reflectometer[4]. Measurements were taken in overlapping spectral regions to enable correlation of data from the



[1,2,3,4] See bibliography

three instruments. Readings were recorded at intervals of 20 millimicrons in the ultraviolet and visible regions and at intervals of 100 millimicrons in the infrared.

5. Difficulty of sample placement precluded taking transmittance measurements in the ultraviolet for certain materials such as excelsior and broom-straw, but since the transmittance of these materials is dependent on configuration and thickness, it may be assumed that the transmittance, at least to a first approximation, is negligible.

6. The accuracies of the reflectance measurements in the ultraviolet, visible, and infrared regions are approximately ± 4, ± 1, and ± 5 per cent, respectively. The corresponding values for the transmittance measurements are ± 2, ± 1, and ± 2 per cent, respectively. These figures give an overall accuracy of the absorptance measurements of about ± 5 per cent. While this accuracy will hold for a particular placement of such samples as shredded newspaper, excelsior, broom straw, scrub brush, dust mop, and cotton waste, slight changes in orientation or packing may produce large changes in reflectance. On the other hand, the measurements are useful for a comparison of the samples' radiant absorptance values relative to various sources.

## RADIANT ABSORPTANCE

7. The total radiant absorptance, $\alpha$, for a given material was computed from the spectral transmittance and reflectance as measured. It was defined by means of the relationship:

$$\alpha = \frac{\int_{.32\mu}^{2.7\mu} \alpha_\lambda E_\lambda \, d\lambda}{\int_{.32\mu}^{2.7\mu} E_\lambda \, d\lambda}$$

$$\alpha_\lambda = 1 - \rho_\lambda - t_\lambda$$

where $\alpha_\lambda$, $\rho_\lambda$, and $t_\lambda$ are the material's spectral absorptance, reflectance, and transmittance, respectively, at the wavelength $\lambda$; $E_\lambda d\lambda$ is the spectral

energy of the source in the wavelength interval from $\lambda$ to $\lambda+d\lambda$.

8. The absorptance coefficients of the samples were computed for 2600°K and 6000°K black-body sources. No corrections were made for atmospheric losses.

## RESULTS

9. The spectral transmittances and reflectances of the various materials are given in Enclosure (1). The total radiant absorptances are given in Enclosure (2).

10. Several observations may be drawn from the data presented in Enclosures (1) and (2). While color determines the amount of visible radiation a material may absorb, as Figures 1 and 2 show in the case of rayon twill linings, the reflectance and absorptance of a light-colored material in the infrared may be the same as those of a dark-colored material. The black materials are not black in the infrared. The transmittance of relatively opaque materials is significant in determining the amount of radiation a material may absorb. It is interesting to note that the spectral transmittance has the same general characteristic as the spectral reflectance. The cellulosic-base fibers (cotton, rayon and paper) have similar absorptance maxima in the infrared.

11. The data of Enclosure (2) indicate that, in correlating laboratory and field exposures, particularly when there is a substantial difference in the temperatures of the two sources, suitable correction must be made for the total radiant absorptance of the material for the particular source of radiation.

Approved:

H. T. Koonce

H. T. KOONCE, CAPTAIN, USN
The Director



sm

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2. J.L. Michaelson, Construction of the General Electric Recording Spectrophotometer, J. Opt. Soc. Am., 28, 365 (1938)

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4. Naval Material Laboratory. A Reflectometer for Measuring Diffuse Reflectance in the Infrared Region. Final Report, Lab. Project 5046, Part 9 (1950).

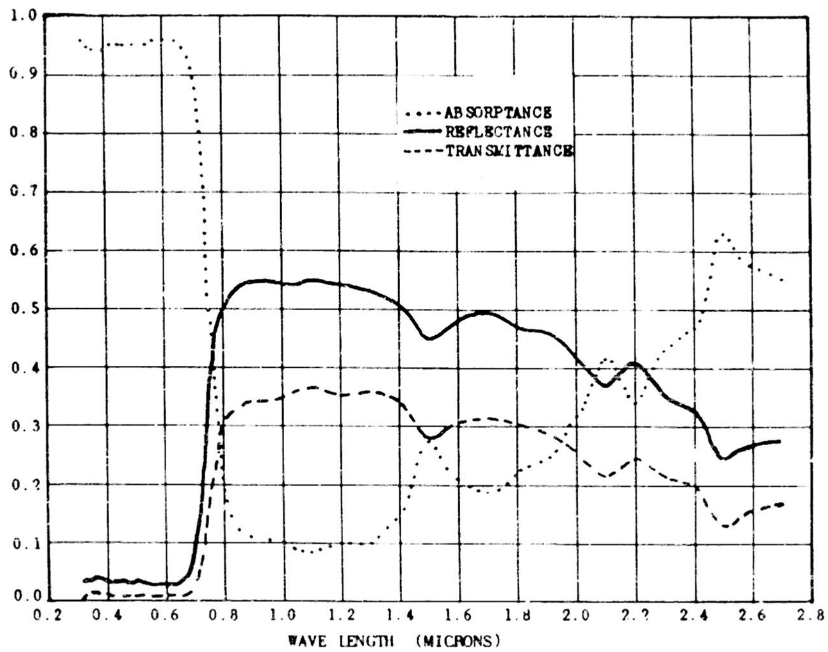


Fig. 1 Spectral Characteristics of Black Rayon Twill Lining

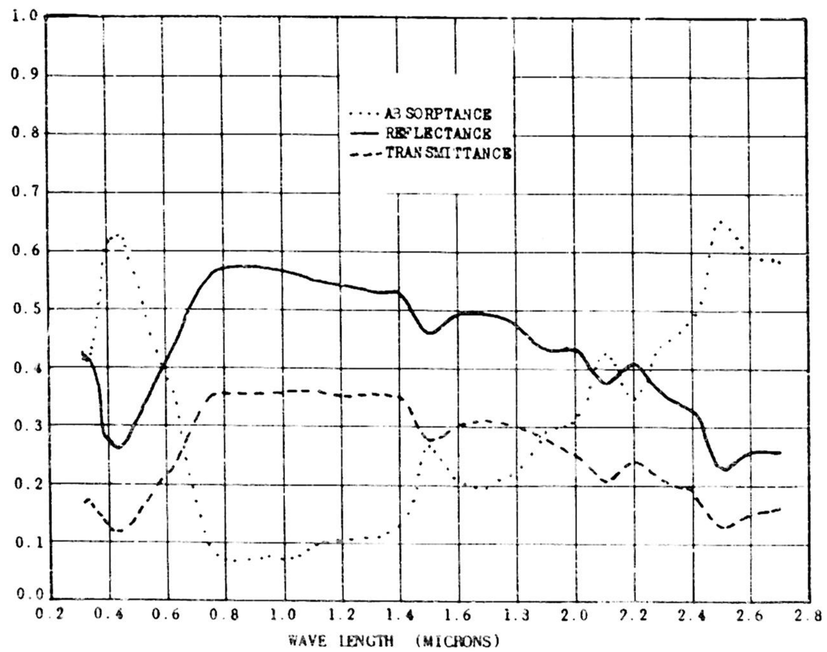


Fig. 2 Spectral Characteristics of Beige Rayon Twill Lining

Lab. Project 5046-3, Part 49 Enclosure (1)

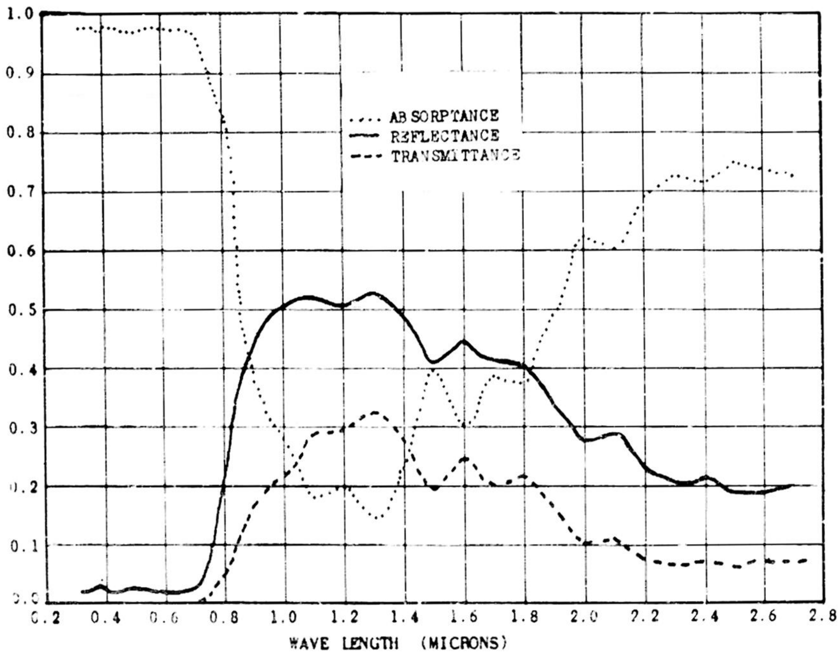


Fig. 3 Spectral Characteristics of Black Wool Flannel

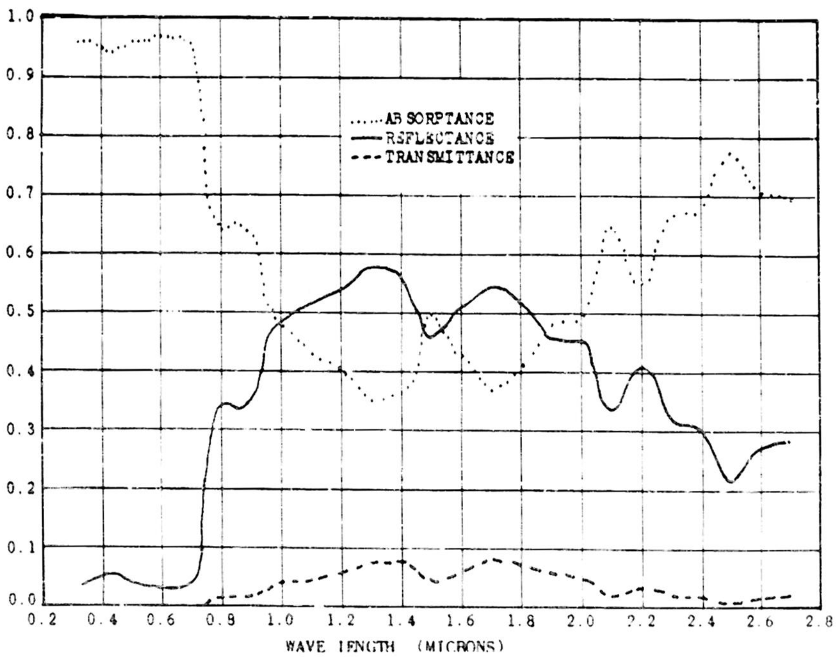


Fig. 4 Spectral Characteristics of Washed Blue Cotton Denim

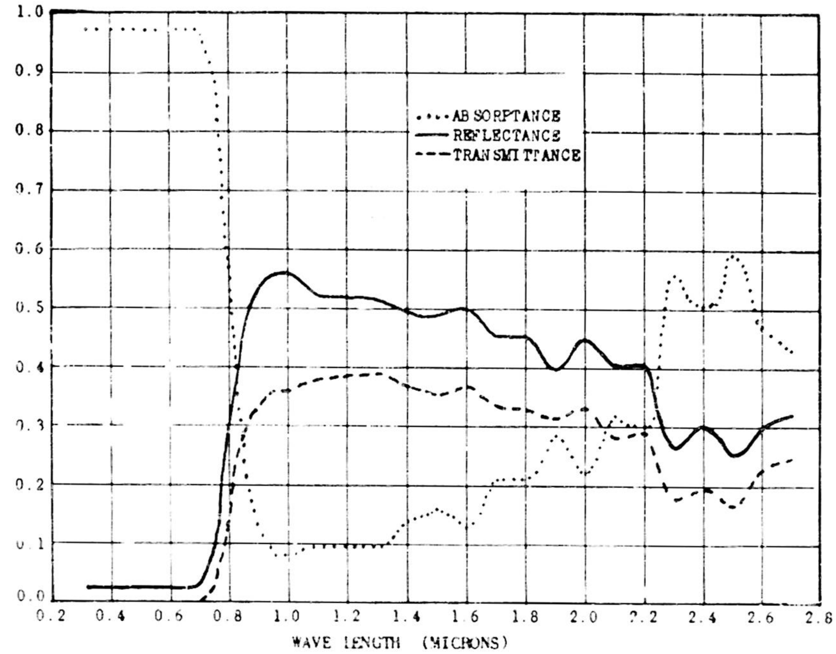


Fig. 5 Spectral Characteristics of Black Acetate Shantung

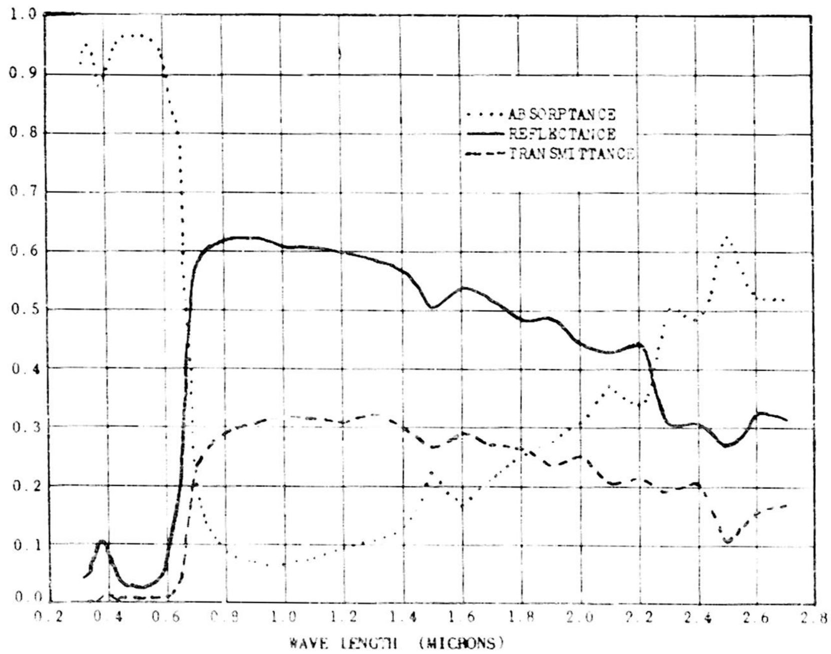


Fig. 6 Spectral Characteristics of Wine Rayon Acetate Drapery

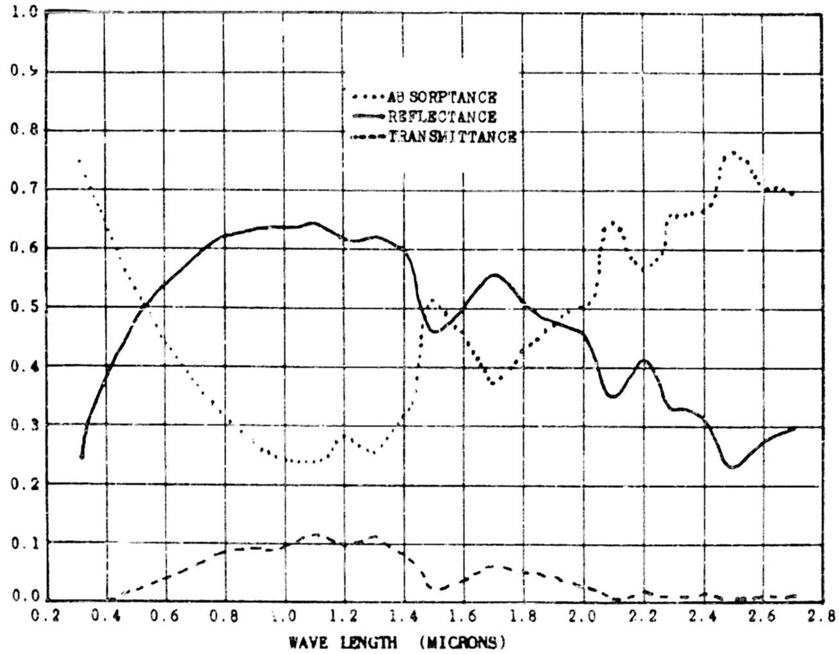


Fig. 7 Spectral Characteristics of Cream Color Venetian Blind Cotton Tape

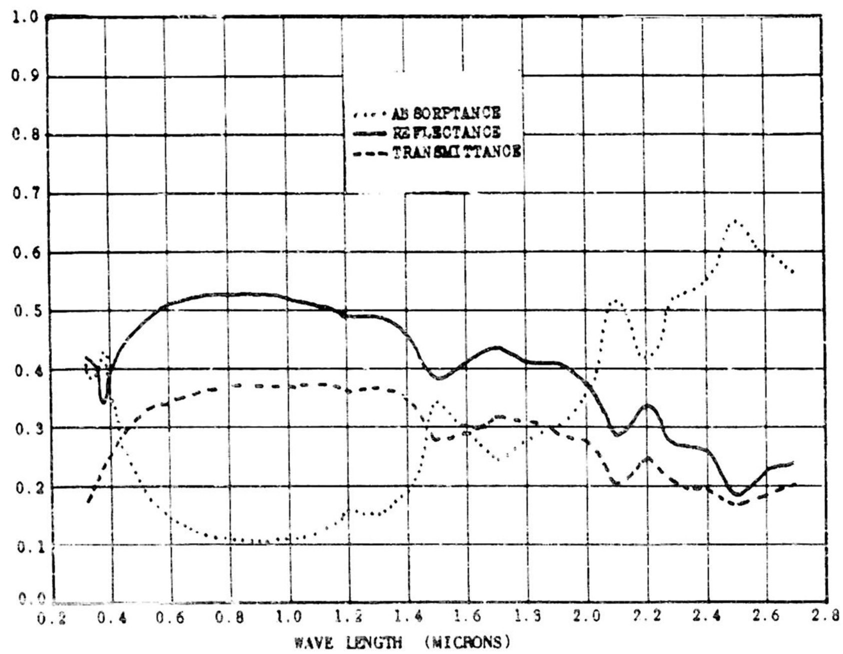


Fig. 8 Spectral Characteristics of Unbleached Cotton Sheeting

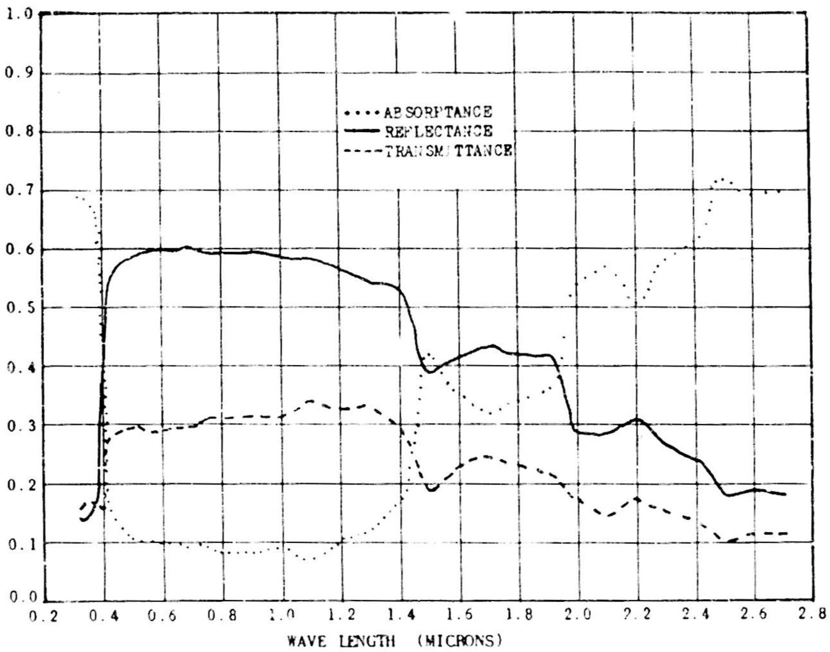


Fig. 9 Spectral Characteristics of Ivory-White Rayon Marquisette Curtain

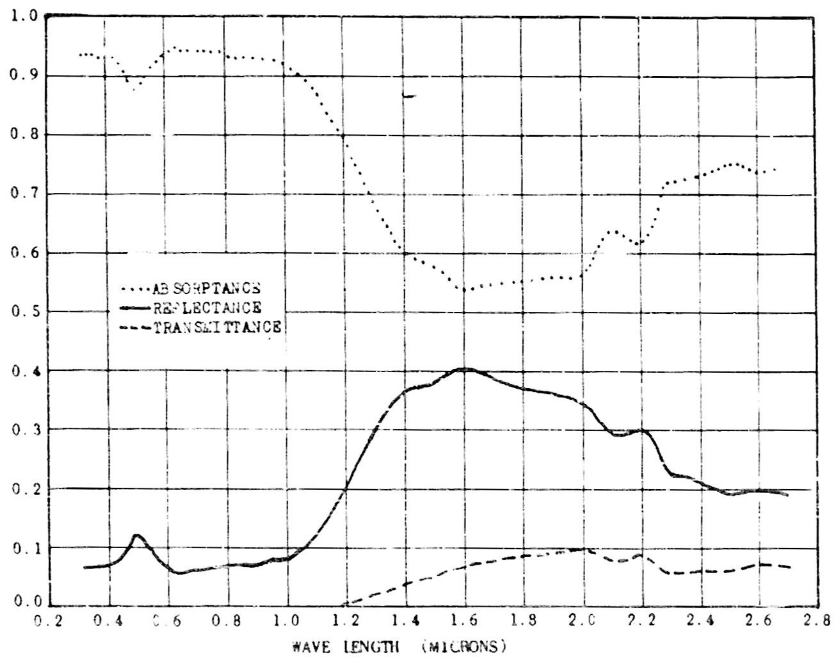


Fig. 10 Spectral Characteristics of Oiled Green Window Shade

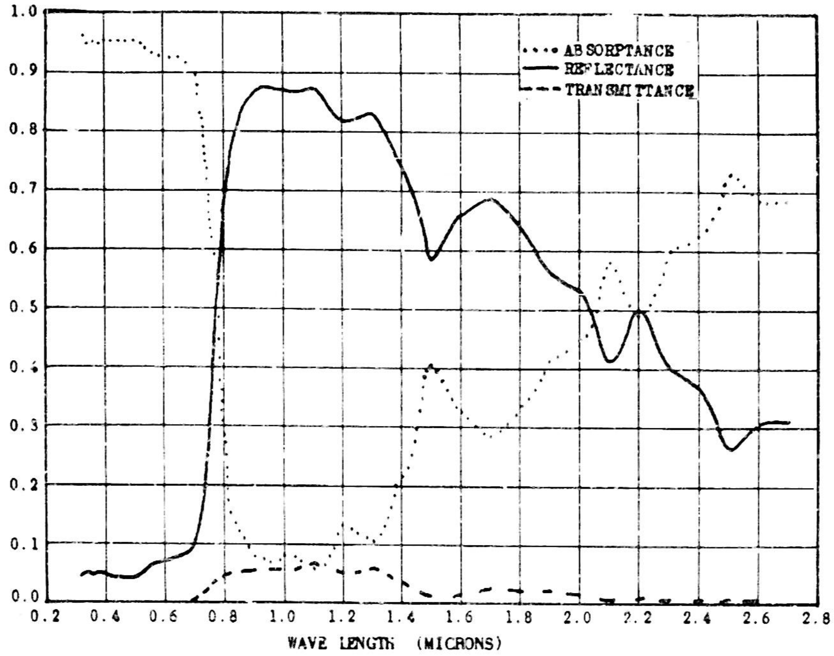


Fig. 11 Spectral Characteristics of 3-Ply Dark Bristol Board

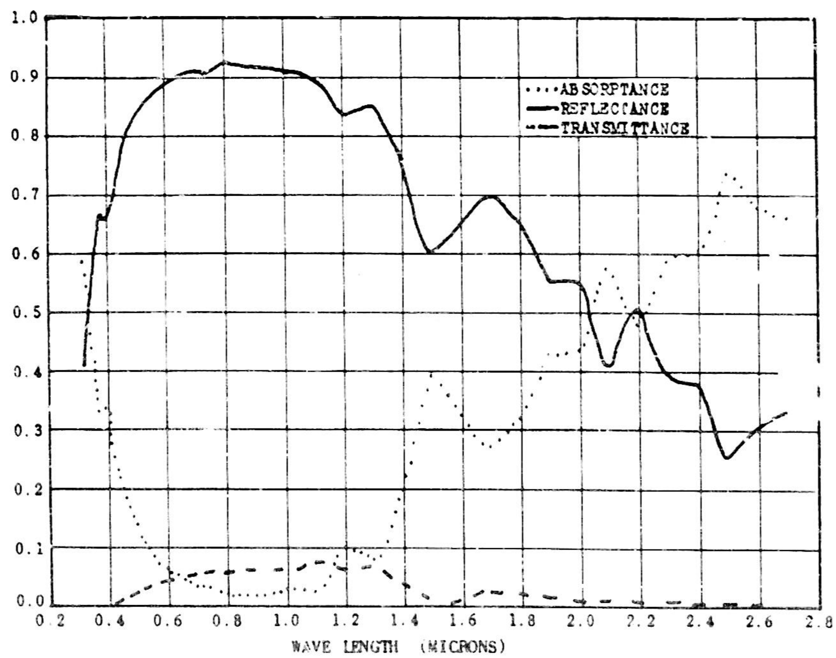


Fig. 12 Spectral Characteristics of 3-Ply White Bristol Board

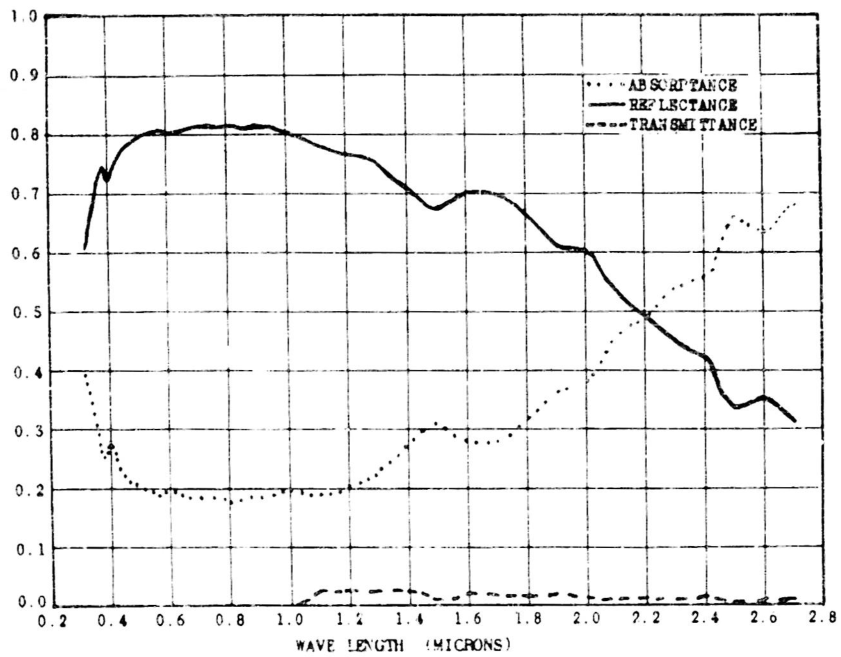


Fig. 13 Spectral Characteristics of 10-Ply White Bristol Board

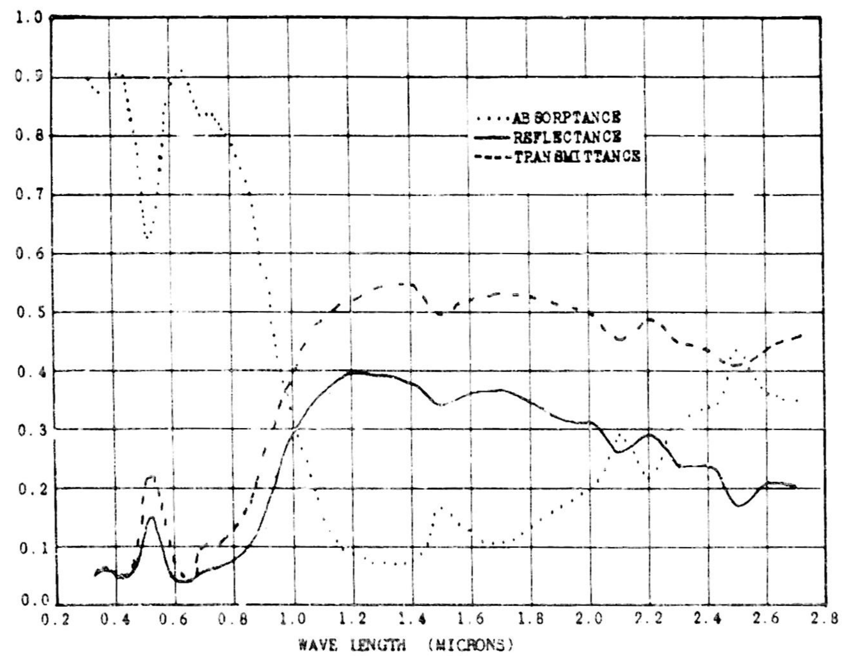


Fig. 14 Spectral Characteristics of Green Crepe Paper

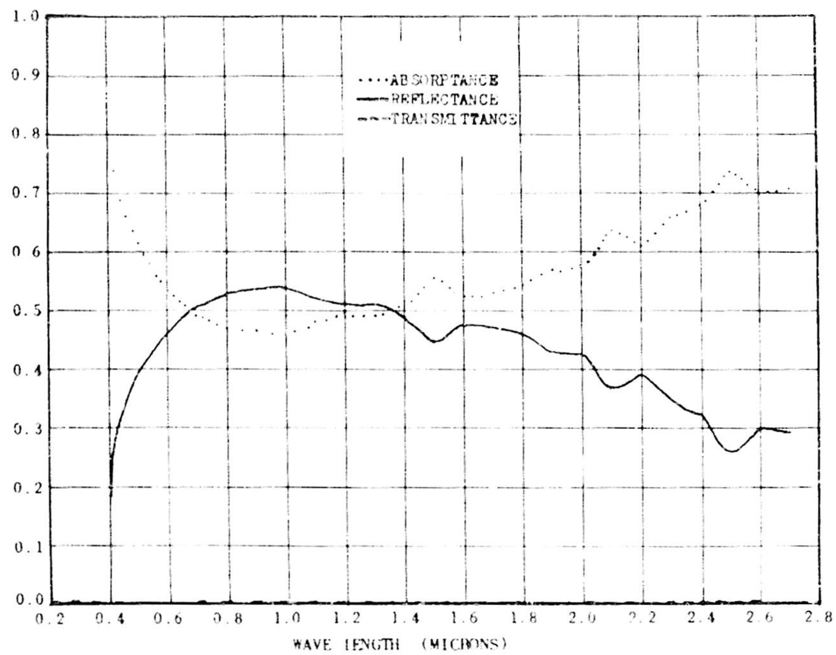


Fig. 15 Spectral Characteristics of Shredded Newspaper

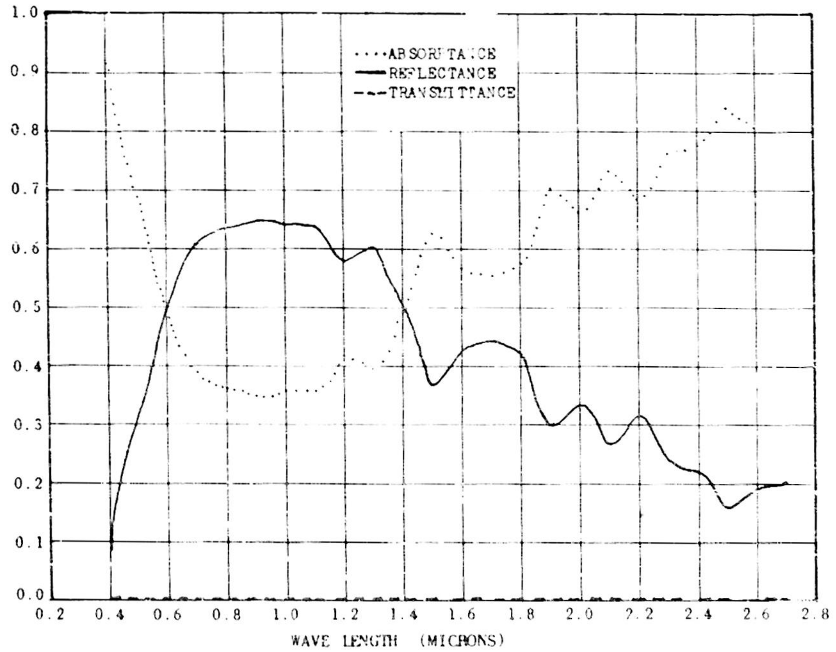


Fig. 16 Spectral Characteristics of Light Yellow Ponderosa Pine Excelsior

Lab. Project 5046-3, Part 49 Enclosure (1)

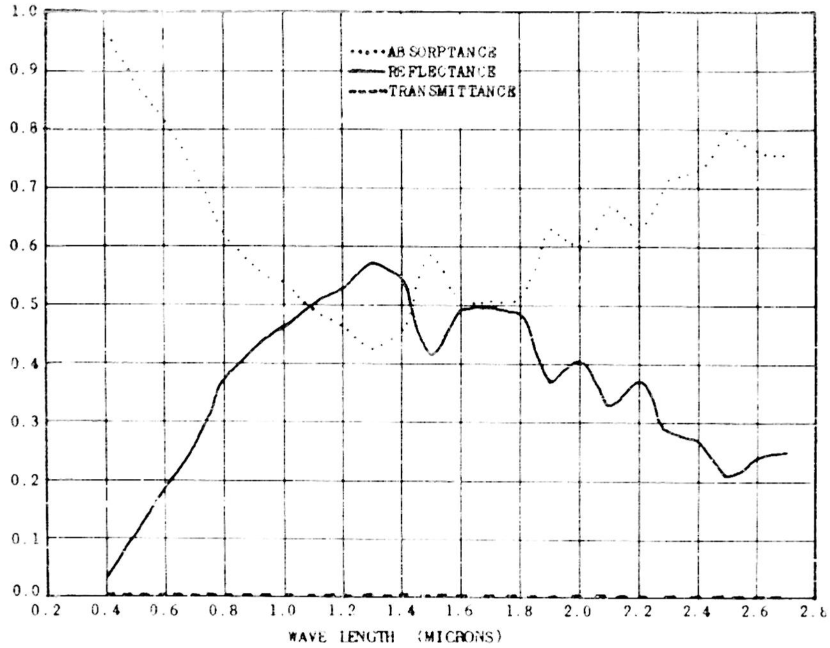


Fig. 17 Spectr l Characteristics of Used Yellow Broom Straw

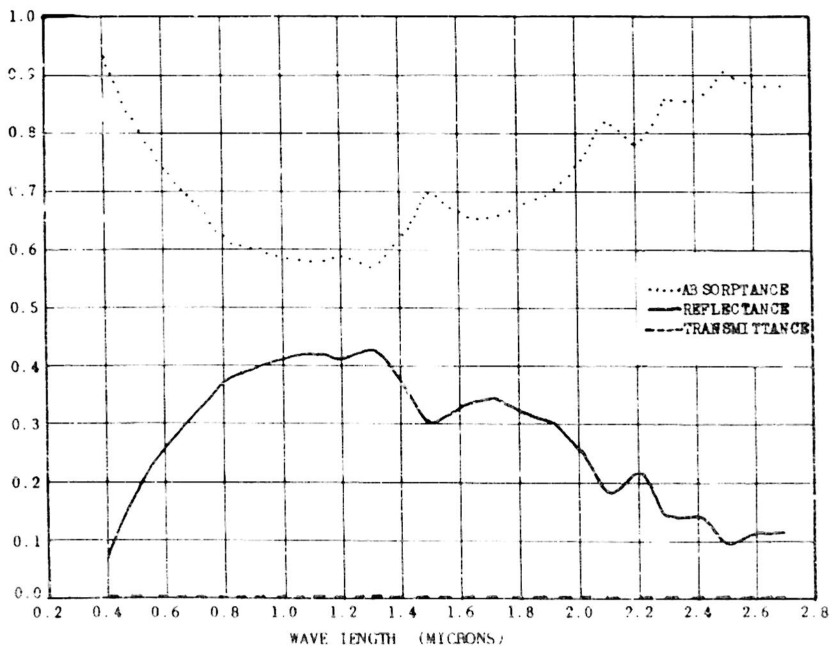


Fig. 18 Spectral Characteristics of Tan Tampico [illegible] Scrub Brush

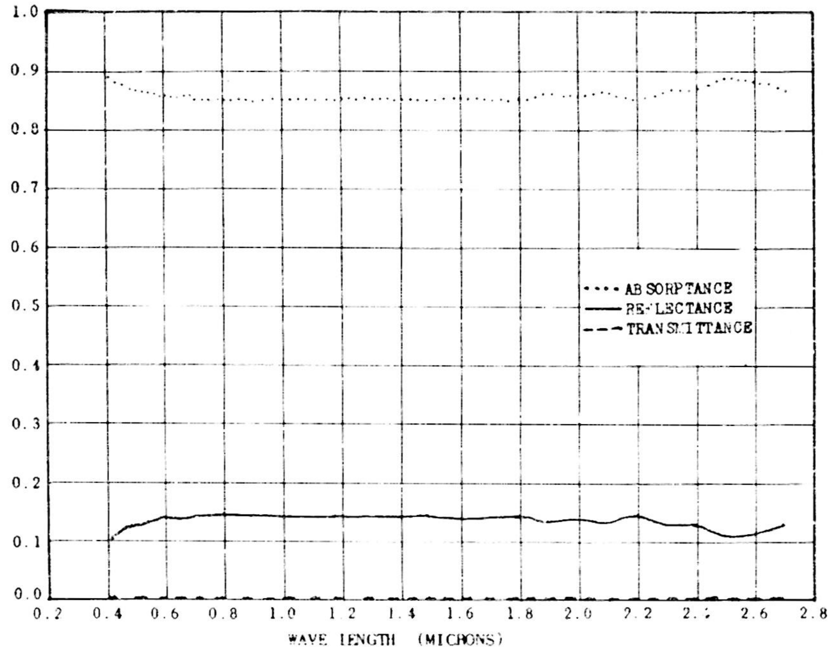


Fig. 19 Spectral Characteristics of Oily Gray Dust Mop

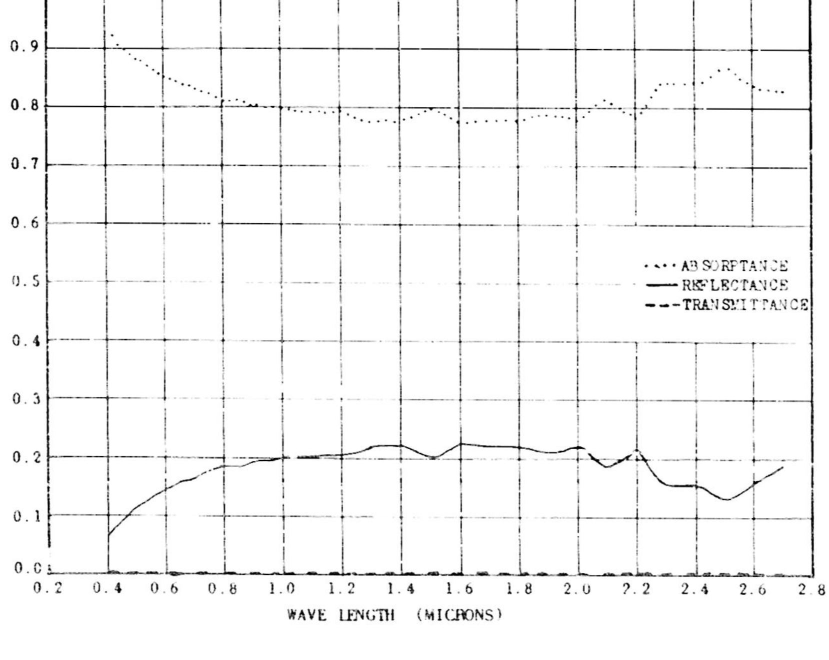


Fig. 20 Spectral Characteristics of Oily Grey Cotton Waste

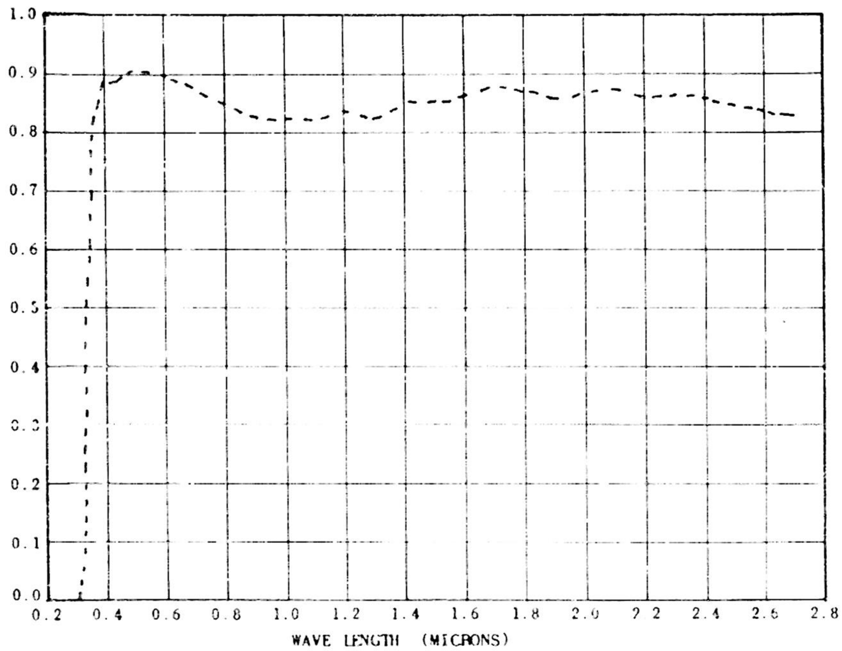


Fig. 21 Transmittance of Single Strength Sodium Window Glass

## RADIANT ABSORPTANCE COEFFICIENTS

| Forest Products Nos. | Sample Description | Radiant Absorptance | |
|---|---|---|---|
| | | 2600°K | 6000°K |
| 454 | Cotton tape from Venetian Blind, old, cream color, 0.032" thick | 0.41 | 0.43 |
| 318 | Window shade, oiled, new, green, 0.014" thick | 0.72 | 0.87 |
| 128 | Bristol board, 3-ply, dark, 0.017" thick | 0.34 | 0.64 |
| 100 | Crepe paper, green, 0.0056" thick | 0.28 | 0.62 |
| 137 | Bristol board, 10-ply, white, 0.044" thick | 0.30 | 0.23 |
| 164 | Bristol board, 3-ply, white, 0.017" thick | 0.30 | 0.16 |
| 429 | Sheeting, unbleached cotton, 0.014" thick | 0.26 | 0.21 |
| 424 | Flannel, wool, black | 0.45 | 0.73 |
| 438 | Rayon twill lining, beige, 0.008" thick | 0.22 | 0.31 |
| 401 | Cotton denim, blue, Washed, 0.025" thick | 0.53 | 0.77 |
| 408 | Acetate shantung, black, 0.0075" thick | 0.28 | 0.66 |
| 441 | Rayon twill lining, black, 0.008" thick | 0.28 | 0.62 |
| 461 | Rayon marquisette curtain, ivory-white, 0.0296" thick | 0.28 | 0.20 |
| 417 | Rayon acetate drapery, wine | 0.24 | 0.53 |
| 196 | Shredded newspaper | 0.54 | 0.55 |
| 209 | Excelsior, Ponderosa Pine, light yellow | 0.53 | 0.53 |
| 362 | Broom straw, yellow, old, used | 0.58 | 0.71 |
| 248 | Tampico fiber, from used scrub brush, tan | 0.68 | 0.72 |
| 353 | Dust mop, oily, dry, gray, diameter of fiber 0.061" | 0.86 | 0.86 |
| 300 | Cotton waste, used, oily, gray | 0.80 | 0.84 |

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